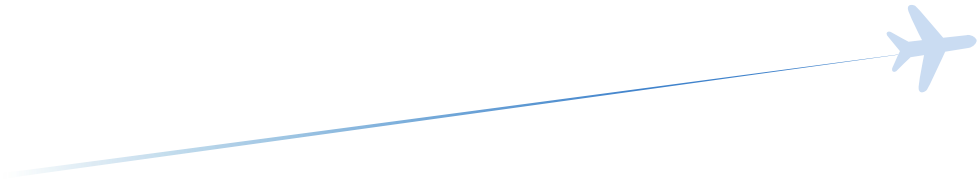

Manuscript for WP7 (outreach for scientific community)

D2.3 – MfWP7

PNOWWA

Grant:	**699221**
Call:	**H2020-SESAR-2015-1**
Topic:	**Sesar-04-2015**
Consortium coordinator:	**Finnish Meteorological Institute**
Edition date:	**[5 March 2018]**
Edition:	**[00.02.00]**
Dissemination level:	**PUBLIC (PU)**

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Elena Saltikoff / FMI	Science and WP Manager	13.2.2018
Seppo Pulkkinen / FMI	Research Scientist	13.2.2018

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Harri Haukka / FMI	Project Manager	14.2.2018
Elena Saltikoff / FMI	Science and WP Manager	14.2.2018

Approved for submission to the SJU By — Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Ari-Matti Harri / FMI	Project Coordinator	15.2.2018
Harri Haukka / FMI	Project Manager	15.2.2018
Elena Saltikoff / FMI	Science and WP Manager	15.2.2018

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.01.00	15.2.2018	First release	Elena Saltikoff Harri Haukka	
00.02.00	6.3.2018	Second version	Harri Haukka Elena Saltikoff	

PNOWWA

PROBABILISTIC NOWCASTING OF WINTER WEATHER FOR AIRPORTS

This document is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 699221 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document describes the manuscript "Nowcasting of Precipitation in the High-Resolution Dallas-Fort Worth (DFW) Urban Radar Remote Sensing Network" by Seppo Pulkkinen, V. Chandrasekar and Ari-Matti Harri.

Table of Contents

Abbreviations

CASA	Collaborative Adaptive Sensing of the Atmosphere
CSI	Critical Success Index
DARTS	Dynamic and. Adaptive Radar Tracking of Storms
DFW	Dallas Fort-Worth
J-STARS	Journal of Selected Topics in Applied Earth Observations and Remote Sensing
MAE	Mean Absolute Error
PNOWWA	Probabilistic Nowcasting of Winter Weather for Airports
STEPS	Short-Term Ensemble Prediction System

List of Figures

None

List of Tables

None

Executive Summary

PNOWWA - Probabilistic Nowcasting of Winter Weather for Airports – is a research project developing methods to support the Air Traffic Management (ATM) challenged by winter weather. In winter 2017, PNOWWA organized a real-time demonstration campaign providing to selected end-users very short-term (0-3h) probabilistic winter weather forecasts in 15 minute time resolution. The nowcasts are based on extrapolation of the movement of weather radar echoes, and ensembles are generated by adding stochastic perturbations.

The manuscript concerns improvements of the STEPS method and adapting it for ultra-high spatial and temporal resolution in urban environment. In addition, the benefits of probabilistic approach over deterministic nowcasting are discussed, and predictability of precipitation is analysed on small spatial scales. Improvement of forecast quality is seen in the CSI scores and attributed to the additional information obtained from the ensembles, which increases the discrimination power of the nowcasts. On the other hand, the improvement seen in MAE is attributed to filtering of small spatial scales having low predictability.

Due to the manuscript not being published by the date of this deliverable, the manuscript is confidential to respect the copyrights of the authors and J-STARS journal. After publication the manuscript will be published in PNOWWA website (full text and/or link to the full text).

1 Abstract of the Manuscript

Nowcasting of Precipitation in the High-Resolution Dallas-Fort Worth (DFW) Urban Radar Remote Sensing Network, *Seppo Pulkkinen, V. Chandrasekar* and *Ari-Matti Harri*

Short-term forecasting (nowcasting) of rainfall is widely used in providing early warning, and therefore has very practical application. The CASA demonstration network deployed in the Dallas Fort-Worth (DFW) area consists of high-resolution X-band radars deployed around the National Weather Service radar WSR-88D, and nowcasting of precipitation is an important product of this network. The current nowcasting technique DARTS was developed in frequency domain using fast Fourier transforms in order to provide nowcasts in a computationally efficient manner. Building on the earlier work on the CASA project and the STEPS methodology, a stochastic nowcasting method is developed and tested for the first time in a small-scale urban environment using high-resolution radar data. The key idea of is to decompose the reflectivity field into multiple spatial scales and generate stochastic perturbations in each scale to account for uncertainties in the nowcasts. It is shown that the proposed method can produce reliable nowcasts and uncertainty estimates up to 45 minutes and performs as well or better than DARTS in terms of the standard critical success index and mean error verification scores. Using the scale decomposition of STEPS, a power-law relationship is derived between the spatial scale and Lagrangian lifetime of precipitation on scales between 500 meters and 50 kilometres.

2 Conclusions

The article was submitted and will be published in J-STARS in 2018. The exact date and issue has not been confirmed by the deadline of this deliverable. Due the manuscript has not been published by the date of this deliverable, the manuscript is not public to respect the copyrights of the authors and J-STARS magazine. After publication the manuscript will released and published in the frame of the PNOWWA project either in PNOWWA webpage or by providing the direct link to the publication.

To be noted that the conclusions of the research work done for the article are included in the article “conclusions” chapter.

References of the Manuscript

1. S. Liguori, M. Rico-Ramirez, A. Schellart, and A. Saul, “Using probabilisticradar rainfall nowcasts and NWP forecasts for flow prediction in urban catchments,” Atmospheric Research, vol. 103, no. Supplement C, pp. 80–95, 2012.
2. S. Thorndahl, T. Einfalt, P. Willems, J. E. Nielsen, M.-C. ten Veldhuis, K. Arnbjerg-Nielsen, M. R. Rasmussen, and P. Molnar, “Weather radar rainfall data in urban hydrology,” Hydrology and Earth System Sciences, vol. 21, no. 3, pp. 1359–1380, 2017.
3. E. Ruzanski, V. Chandrasekar, and Y. Wang, “The CASA nowcasting system,” Journal of Atmospheric and Oceanic Technology, vol. 28, no. 5, pp. 640–655, 2011.
4. S. Liguori and M. A. Rico-Ramirez, “A review of current approaches to radar-based quantitative precipitation forecasts,” International Journal of River Basin Management, vol. 12, no. 4, pp. 391–402, 2014.
5. U. Germann and I. Zawadzki, “Scale-dependence of the predictability of precipitation from continental radar images. Part I: Description of the methodology,” Monthly Weather Review, vol. 130, no. 12, pp. 2859–2873, 2002.
6. N. E. Bowler, C. E. Pierce, and A. W. Seed, “STEPS: A probabilistic precipitation forecasting scheme which merges an extrapolation nowcast with downscaled NWP,” Quarterly Journal of the Royal Meteorological Society, vol. 132, no. 620, pp. 2127–2155, 2006.
7. E. Ruzanski and V. Chandrasekar, “An investigation of the short-term predictability of precipitation using high-resolution composite radar observations,” Journal of Applied Meteorology and Climatology, vol. 51, no. 5, pp. 912–925, 2012.
8. B. J. Turner, I. Zawadzki, and U. Germann, “Predictability of precipitation from continental radar images. Part III: Operational nowcasting implementation (MAPLE),” Journal of Applied Meteorology, vol. 43, no. 2, pp. 231–248, 2004.
9. E. Ruzanski and V. Chandrasekar, “Scale filtering for improved nowcasting performance in a high-resolution x-band radar network,” IEEE Transactions on Geoscience and Remote Sensing, vol. 49, no. 6, pp. 2296–2307, 2011.
10. B. Radhakrishna, I. Zawadzki, and F. Fabry, “Predictability of precipitation from continental radar images. Part V: Growth and decay,” Journal of the Atmospheric Sciences, vol. 69, no. 11, pp. 3336–3349, 2012.

11. M. Berenguer, D. Sempere-Torres, and G. G. S. Pegram, “SBMcast an ensemble nowcasting technique to assess the uncertainty in rainfall forecasts by Lagrangian extrapolation,” Journal of Hydrology, vol. 404, no. 34, pp. 226–240, 2011.

12. A. W. Seed, C. E. Pierce, and K. Norman, “Formulation and evaluation of a scale decomposition-based stochastic precipitation nowcast scheme,” Water Resources Research, vol. 49, no. 10, pp. 6624–6641, 2013.

13. L. Foresti, M. Reyniers, A. Seed, and L. Delobbe, “Development and verification of a real-time stochastic precipitation nowcasting system for urban hydrology in Belgium,” Hydrology and Earth System Sciences, vol. 20, no. 1, pp. 505–527, 2016.

14. A. W. Seed, “A dynamic and spatial scaling approach to advection forecasting,” Journal of Applied Meteorology, vol. 42, no. 3, pp. 381–388, 2003.

15. M. Proesmans, L. van Gool, E. Pauwels, and A. Oosterlinck, “Determination of optical flow and its discontinuities using non-linear diffusion,” in Computer Vision ECCV ’94, ser. Lecture Notes in Computer Science, J.-O. Eklundh, Ed. Springer Berlin Heidelberg, 1994, vol. 801, pp. 294–304.

16. B. Kedem and L. S. Chiu, “On the lognormality of rain rate,” Proceedings of the National Academy of Sciences of the United States of America, vol. 84, no. 4, pp. 901–905, 1987.

17. D. Veneziano, R. L. Bras, and J. D. Niemann, “Nonlinearity and self-similarity of rainfall in time and a stochastic model,” Journal of Geophysical Research: Atmospheres, vol. 101, no. D21, pp. 26 371–26 392, 1996.

18. L. Foresti and A. Seed, “The effect of flow and orography on the spatial distribution of the very short-term predictability of rainfall from composite radar images,” Hydrology and Earth System Sciences, vol. 18, no. 11, pp. 4671–4686, 2014.

19. M. B. Priestley, Spectral analysis and time series. London: Academic Press, 1981.

20. N. E. H. Bowler, C. E. Pierce, and A. Seed, “Development of a precipitation nowcasting algorithm based upon optical flow techniques,”Journal of Hydrology, vol. 288, no. 12, pp. 74–91, 2004.

21. L. Li, W. Schmid, and J. Joss, “Nowcasting of motion and growth of precipitation with radar over a complex orography,” Journal of Applied Meteorology, vol. 34, no. 6, pp. 1286–1300, 1995.

22. S. Laroche and I. Zawadzki, “A variational analysis method for retrieval of three-dimensional wind field from single-doppler radar data,” Journal of the Atmospheric Sciences, vol. 51, no. 18, pp. 2664–2682, 1994.

23. “Retrievals of horizontal winds from single-doppler clear-air data by methods of cross correlation and variational analysis,” Journal of Atmospheric and Oceanic Technology, vol. 12, no. 4, pp. 721–738, 1995.

24. B. K. Horn and B. G. Schunck, “Determining optical flow,” Artificial Intelligence, vol. 17, pp. 185–204, 1981.

25. E. H. Adelson, C. H. Anderson, J. R. Bergen, P. J. Burt, and J. M.Ogden, “Pyramid methods in image processing,” RCA Engineer, vol. 29, no. 6, pp. 33–41, 1984.

26. A. Atencia and I. Zawadzki, “A comparison of two techniques for generating nowcasting ensembles. Part I: Lagrangian ensemble technique,” Monthly Weather Review, vol. 142, no. 11, pp. 4036–4052, 2014.

27. J. Br¨ocker and L. A. Smith, “Increasing the reliability of reliability diagrams,” Weather and Forecasting, vol. 22, no. 3, pp. 651–661, 2007.

28. I. T. Jolliffe and D. B. Stephenson, Forecast Verification: A Practitioner’s Guide in Atmospheric Science. Chichester, UK: John Wiley & Sons, 2003.

29. T. M. Hamill, “Interpretation of rank histograms for verifying ensemble forecasts,” Monthly Weather Review, vol. 129, no. 3, pp. 550–560, 2001.

30. T. Gneiting, F. Balabdaoui, and A. E. Raftery, “Probabilistic forecasts, calibration and sharpness,” Journal of the Royal Statistical Society: Series B (Statistical Methodology), vol. 69, no. 2, pp. 243–268, 2007.

31. P. J. Rossi, V. Chandrasekar, V. Hasu, and D. Moisseev, “Kalman filteringbased probabilistic nowcasting of object-oriented tracked convective storms,” Journal of Atmospheric and Oceanic Technology, vol. 32, no. 3, pp. 461–477, 2015.

32. M. L. Weisman and J. B. Klemp, Characteristics of Isolated Convective Storms. Boston, MA: American Meteorological Society, 1986, pp. 331–358.